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Drift Waves in a Helicon Plasma

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Drift waves are studied in a high density helicon plasma in linear magnetic geometry. Drift waves are destabilized in the pressure gradient region by the ambient magnetic field acting as the control parameter. Saturated drift modes as well as turbulent states are observed by spatiotemporal probe diagnostics. Their propagation and radial mode structure is related to the time averaged plasma density and plasma potential profiles.

1. Introduction

Drift waves play an important role in many dynamical processes in magnetized plasmas. The early studies were already motivated by the enhanced transport of plasma across the magnetic field [1]. In this context drift waves have gained attention during the last two decades because experimental findings as well as numerical simulations strongly suggest a strong contribution of drift waves to the development of turbulence in the edge plasma of fusion devices [2, 3]. This paper presents observations of drift waves in a high density plasma in homogeneous magnetic field geometry. Particular attention is paid to a controllable destabilization of single coherent modes.

2. Experimental Setup

The experiments were conducted in the linear VINETA device [4] schematically shown in Fig. 1. It consists of for identical modules, each with a separate set of magnetic field coils and power supply. In the present experiments the device is homogeneously magnetized with a spatial magnetic ripple of less than 1%. The plasma is produced by a conventional helicon plasma source, located at one end of the discharge chamber. At an rf input power of typically 2.5kW a peak plasma density of $\approx 1 \cdot 10^{19}\mathrm{m}^{-3}$ is achieved at a relatively low electron temperature of 3eV. Time averaged plasma profiles are obtained by spatially resolved electrostatic probe measurements and evaluation of the probe characteristics. A typical radial profile of the plasma density and the plasma potential is shown in Fig. 2. The plasma density is of almost perfect Gaussian shape. The plasma potential is positive and shows a flat top in the core, whereas in the gradient regions the potential decreases parabolically. These profiles

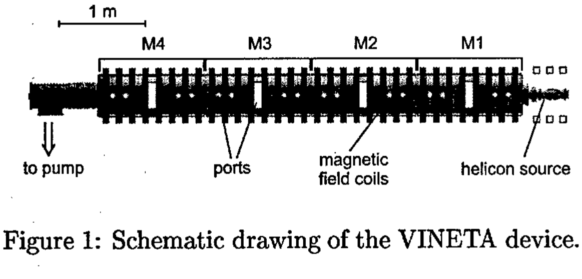

Figure 1: Schematic drawing of the VINETA device.

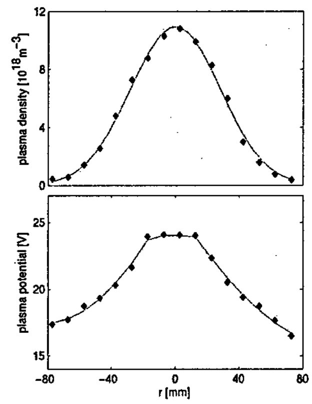

Figure 2: Measured radial profiles of the plasma density and the plasma potential as obtained by probe measurements (markers). A Gaussian is fitted to the density profile, two parabolic function are fitted to the plasma potential gradients.

lead to two important consequences. First, the $E \times B$ rotation of the plasma is strongly sheared in the density gradient region. Second, the $E \times B$ rotation is anti-parallel to the electron diamagnetic drift direction. Fluctuations of the plasma density are measured by constantly biased probes. The ion saturation current is taken as proportional to density fluctuations, i.e. electron temperature fluctuation are neglected. These probes are operated as single probes or as an azimuthal 64 probe array recording simultaneously fluctuations on an azimuthal plasma circumference [5].

3. Results

Destabilization of drift waves is achieved using the ambient magnetic field as control parameter. This directly changes the effective ion gyroradius ϱ_s, whereas the time-averaged plasma profiles turned out to remain essentially uninfluenced. Consequently, the ratio between effective ion gyroradius and density gradient scale length ϱ_s/L_n is changed via the magnetic field, which directly controls driving of the drift waves. In Fig. 3 recordings of density fluctuations together with the respective frequency-mode number spectra are shown for three different magnetic fields. For $B = 75$mT, Fig. 3 (b), a single coher-

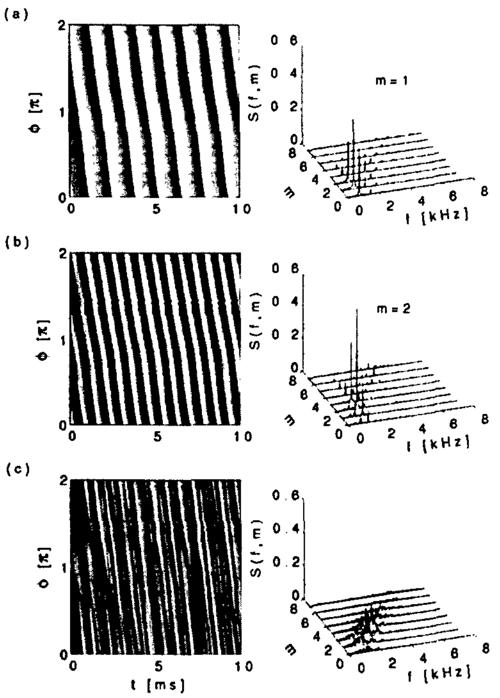

Figure 3: Spatiotemporal diagram of drift wave density fluctuations as obtained with an azimuthal probe array for different magnetic field strengths $B = 60\text{mT}$ in (a), $B = 75\text{mT}$ in (b), and $B = 90\text{mT}$ in (c). Additionally, the respective frequency-mode number spectra are shown.

ent $m = 2$ drift mode is observed with two maxima and two minima around a plasma circumference. The frequency-mode number spectrum is strongly peaked at this mode and a frequency of 1kHz. This frequency corresponds to a phase velocity of the drift wave given by the electron diamagnetic drift Doppler shifted by the plasma $E \times B$ rotation, which reduces the propagation speed. The mode structure in a plane perpendicular to the ambient magnetic field is measured via cross-correlation measurements. Density fluctuations in an azimuthal plane are correlated to density fluctuations at a fixed spatial position in the maximum density gradient region. Fig. 4 shows the respective values of the cross-correlation function at a fixed time instant. The $m = 2$ mode structure is clearly observed. The correlation decreases towards the plasma core, where the density gradient vanishes. Coherent fluctuations are found to the far outer boundary of the density profile. The mode structure is distorted in radial direction, which can be addressed to the sheared rotation of the plasma column.
Changing the magnetic field dramatically influences the drift dynamics. For lower magnetic field, Fig. 3 (a), the dominant frequency is lowered and a $m = 1$ drift mode dominates. Increase of the magnetic field, Fig. 3 (c), destabilizes different modes, which

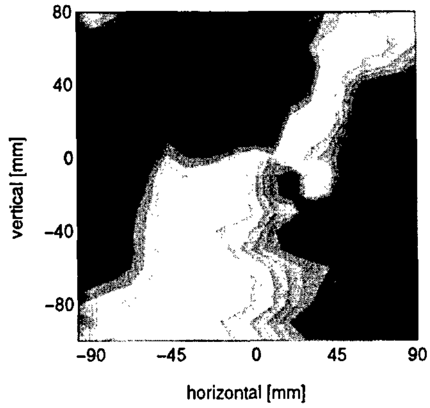

Figure 4: Cross-correlation measurement in a azimuthal plane perpendicular to the ambient magnetic field. Shown are the values of the cross-correlation function at a fixed time delay between a fixed and a scanning probe.

interact nonlinearly and lead to a weakly developed turbulent state. The spectrum here is broadened and no coherent modes are observed in the spatiotemporal diagram.

4. Conclusions

An experimental study of drift waves in a high-density helicon discharge is presented. It is shown that via the magnetic field good control over the dynamical states of drift waves is achieved, most likely by changing the drift scale length ϱ_s. By this control parameter coherent modes can be destabilized as well as mode interaction regimes and weakly developed turbulence. For low magnetic field, i.e. large ϱ_s, modes with low mode numbers are predominantly destabilized. For higher magnetic fields the dominant mode number increases and single drift modes with mode numbers ranging from $m = 1 \dots 6$ can be observed. For high magnetic fields nonlinear mode coupling results in weakly developed turbulent state.

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